International Gas Turbine Conference 2015 Tokyo
November 15(Sun.)-20(Fri.), 2015

Investigation of Unsteady Flow Interaction between an Ultra-Compact Inlet and a Transonic Fan

Chunill Hah[1], Douglas Rabe[2] and Angie Scribben[2]

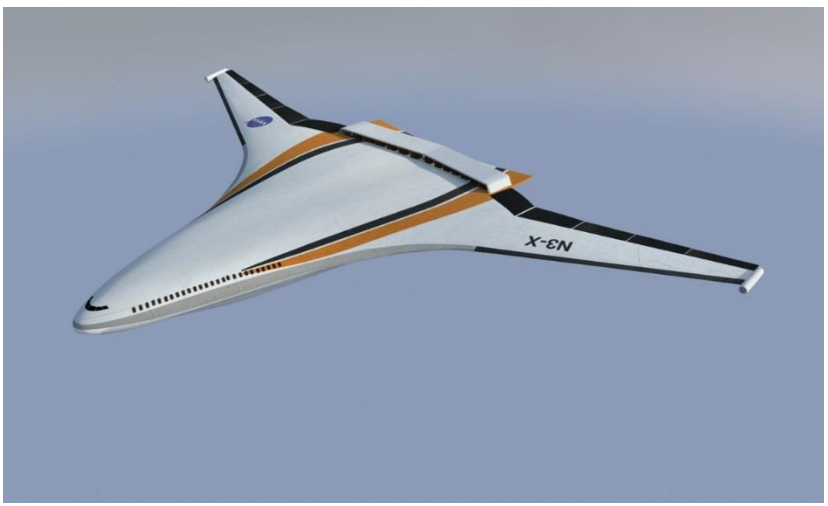
[1] NASA Glenn Research Center
MS 5-11, Cleveland, Ohio 44135
[2] AFRL, WPAFB, Ohio 45433

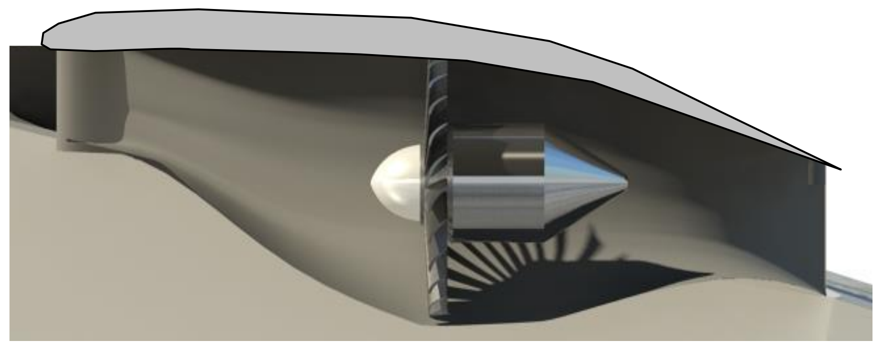
Background

- Development of ultra-compact inlet for UAV.
- Boundary layer ingesting propulsion.

Ultra-compact inlet

Embedded engine



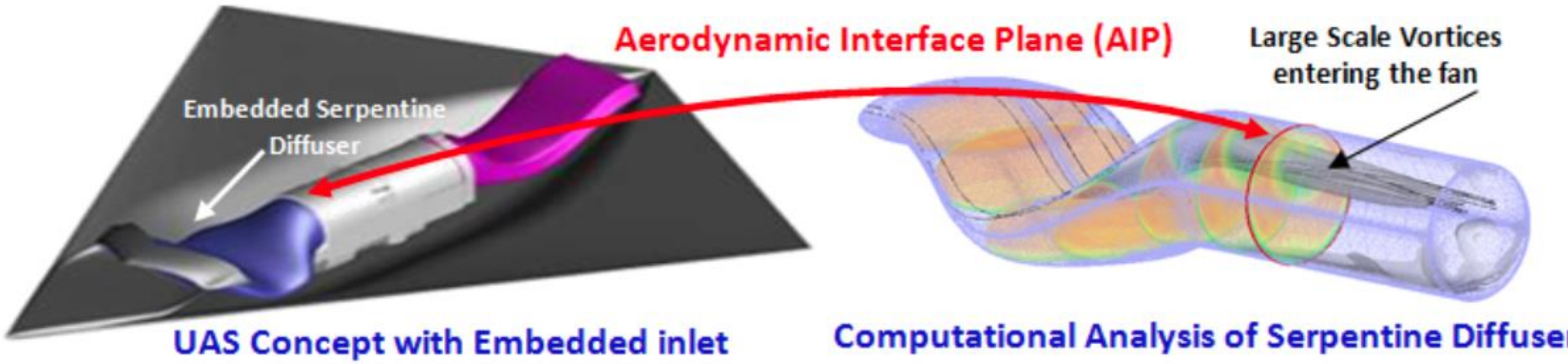


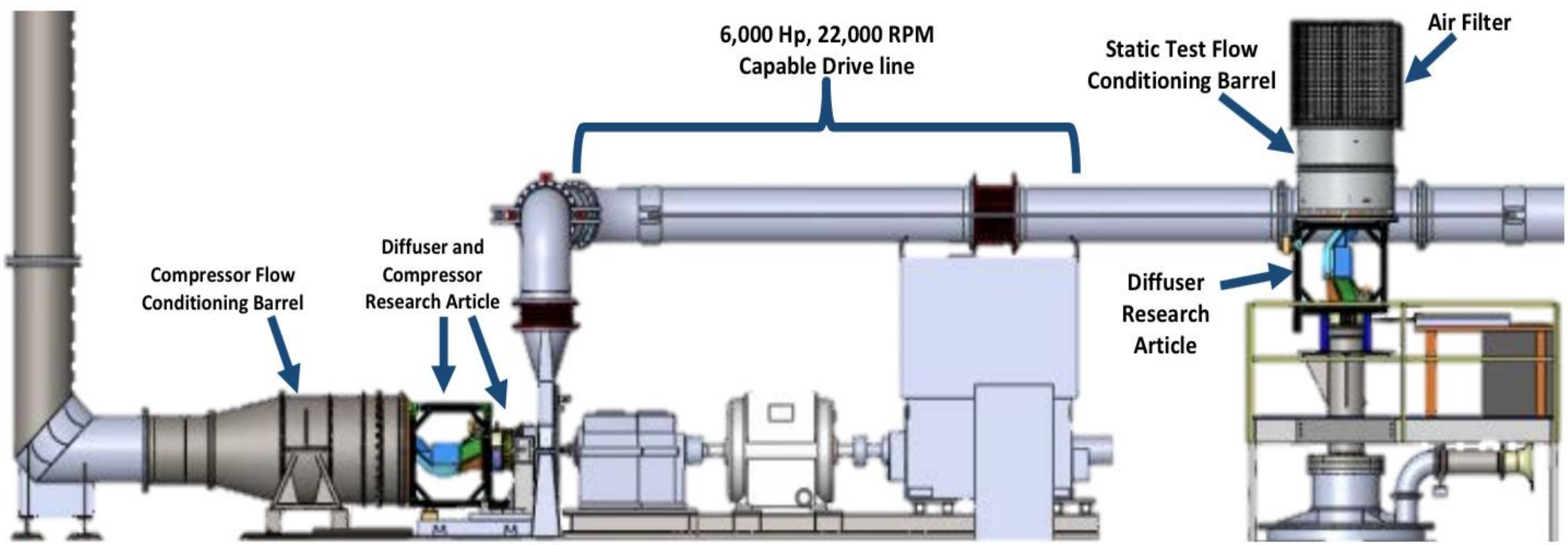
Objectives

- Effects of inlet distortion on stall margin and efficiency.
- Development of distortion-tolerant fan/engine.

LM inlet/ VAIIPR Fan test rig

Boeing inlet/ GE Rotor4 test rig

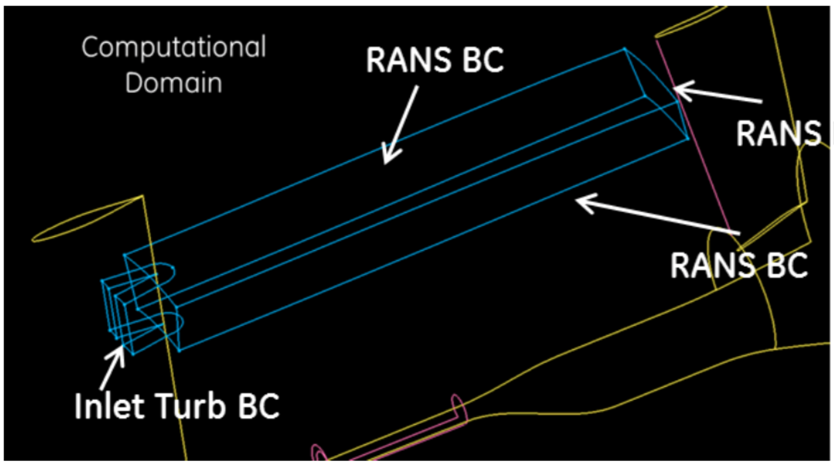


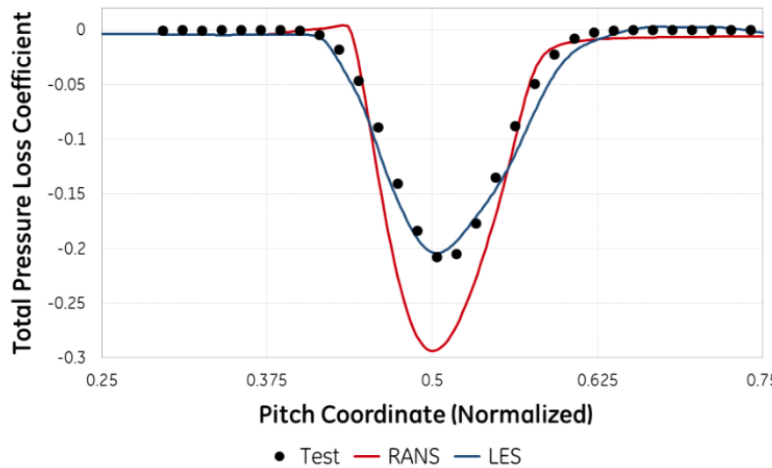


Why LES for inlet/fan analysis ?

- URANS : Effects due to entire turbulence scales are modeled. Solution depends on turbulence model. Difficult for separated flow, wake development, Reynolds number effects, unsteady pressure field.
- LES : Significant increase in computing cost. Requires large computational grid. Needs further development/validation for high speed flow.

Full LES simulation of IGV wake





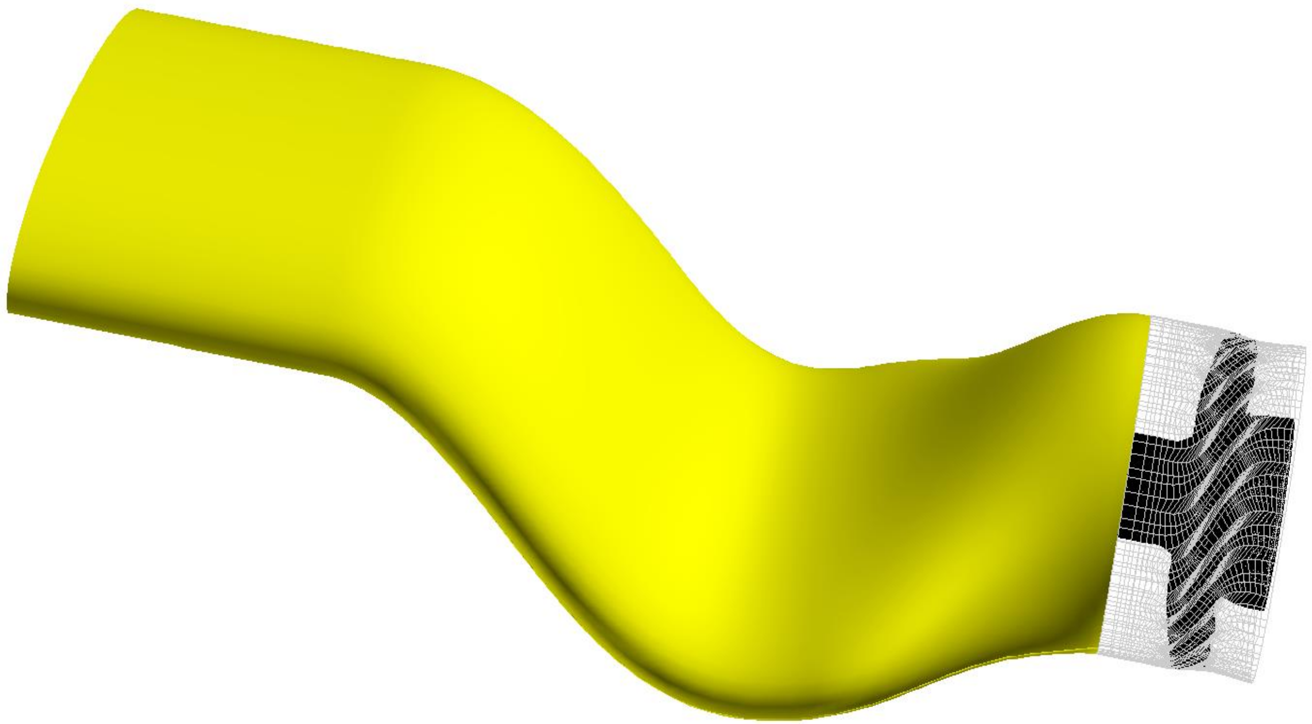
Embedded LES simulation

Numerical Procedure

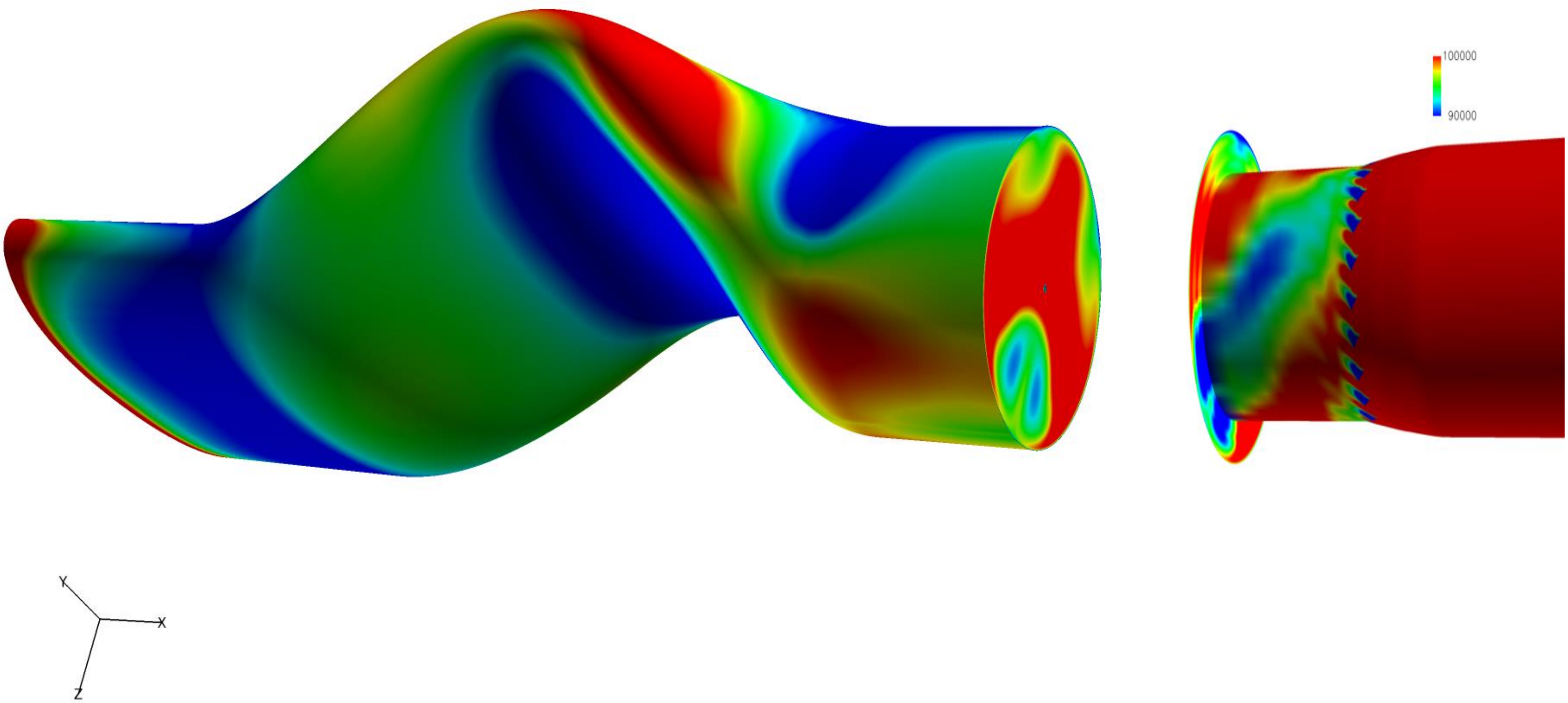
- Pressure based method for incompressible and compressible flow application.
- 3^{rd}-order scheme for convection terms.
- 2^{nd}-order central differencing for diffusion terms.
- Sub-iterations at each time step.
- RANS & URANS : two-equation model.

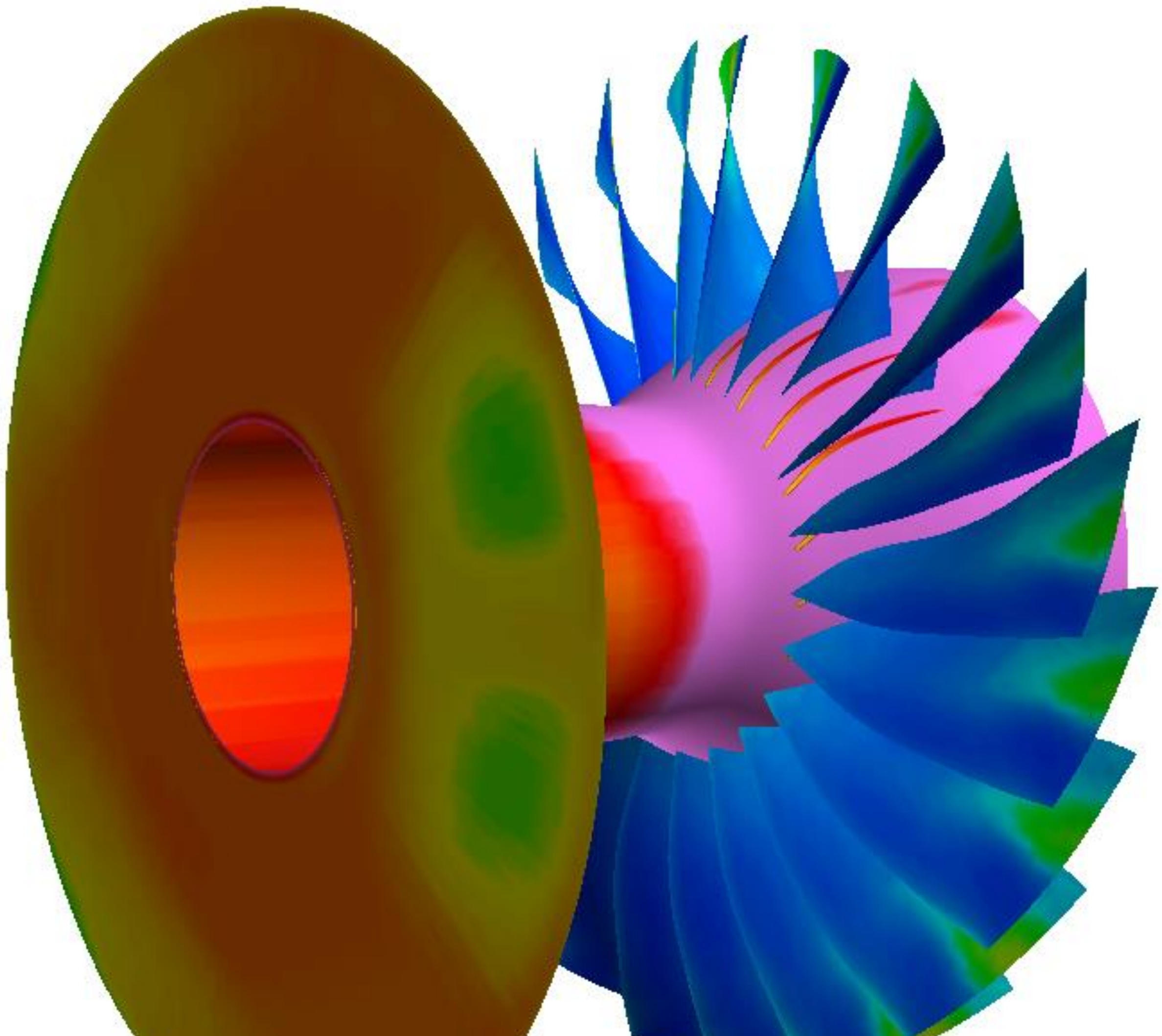
  LES : dynamic model for sub-grid stress.

Simplified inlet/fan configuration

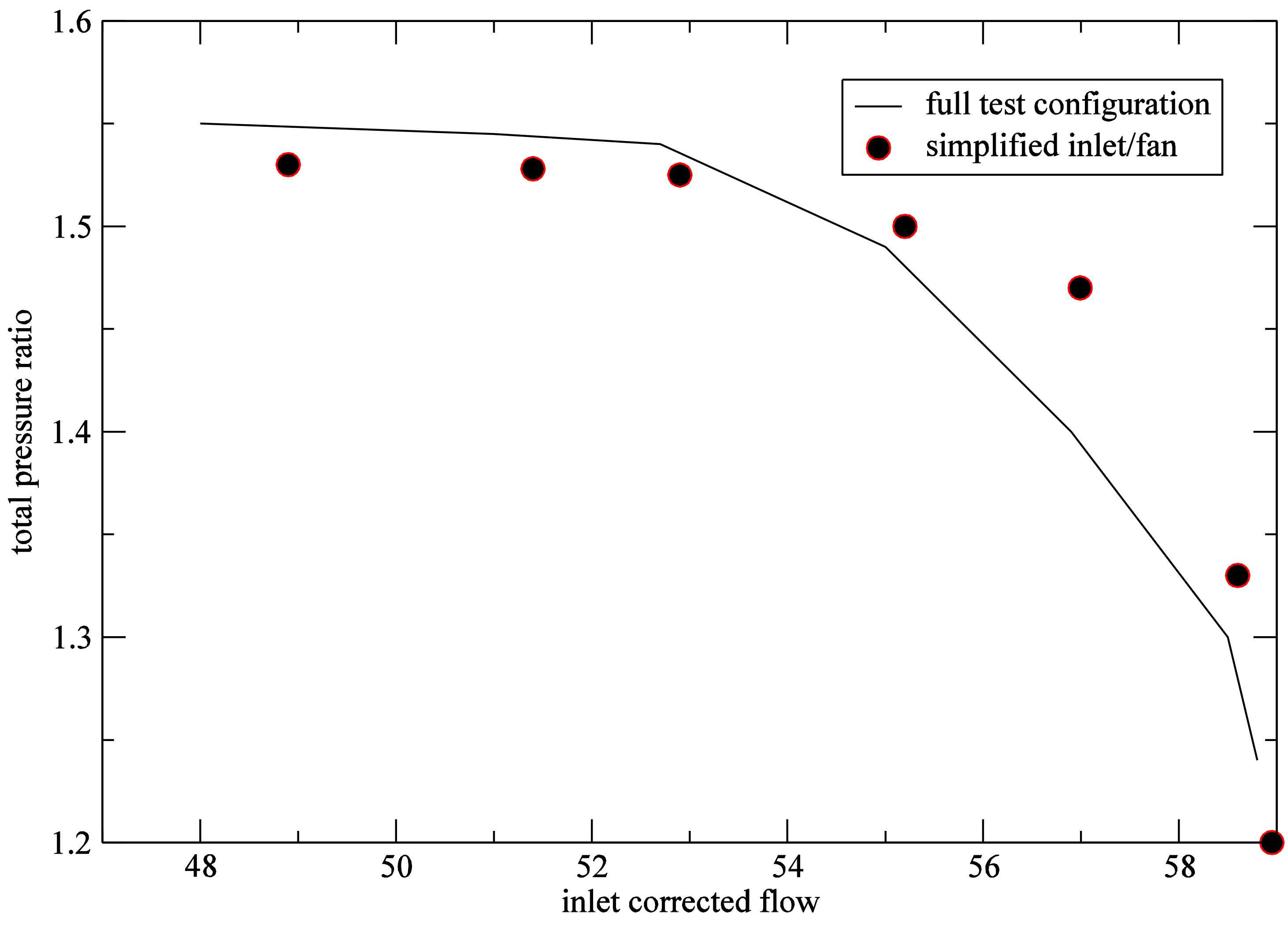


Inlet/fan unsteady simulation

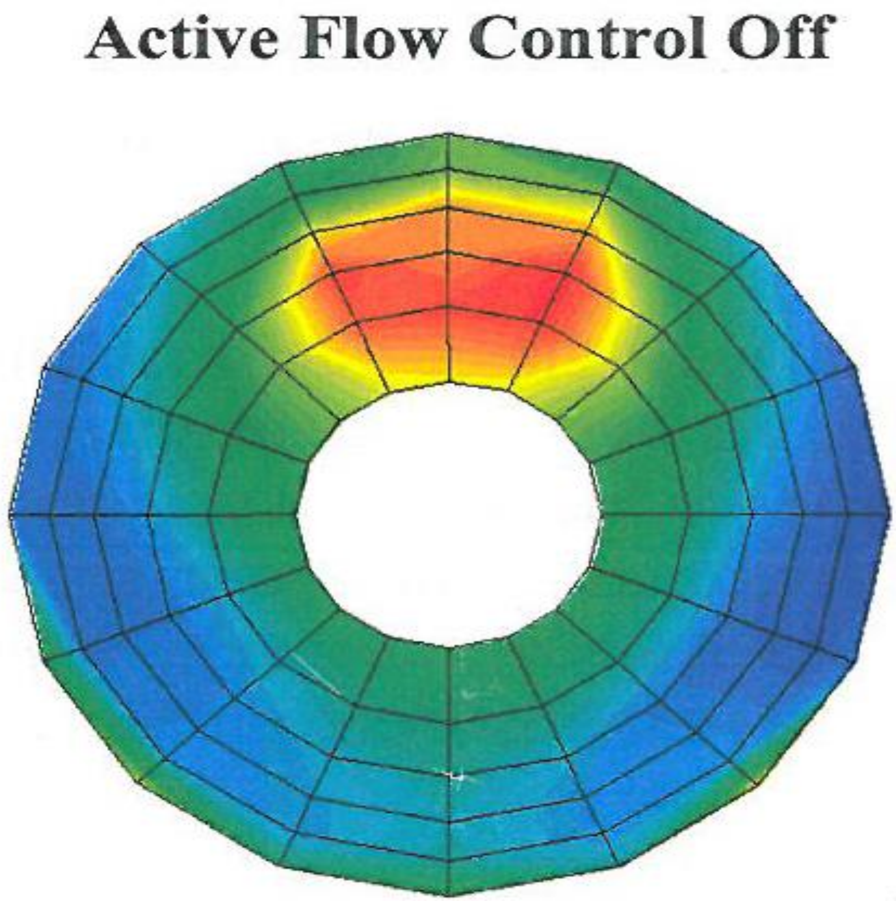




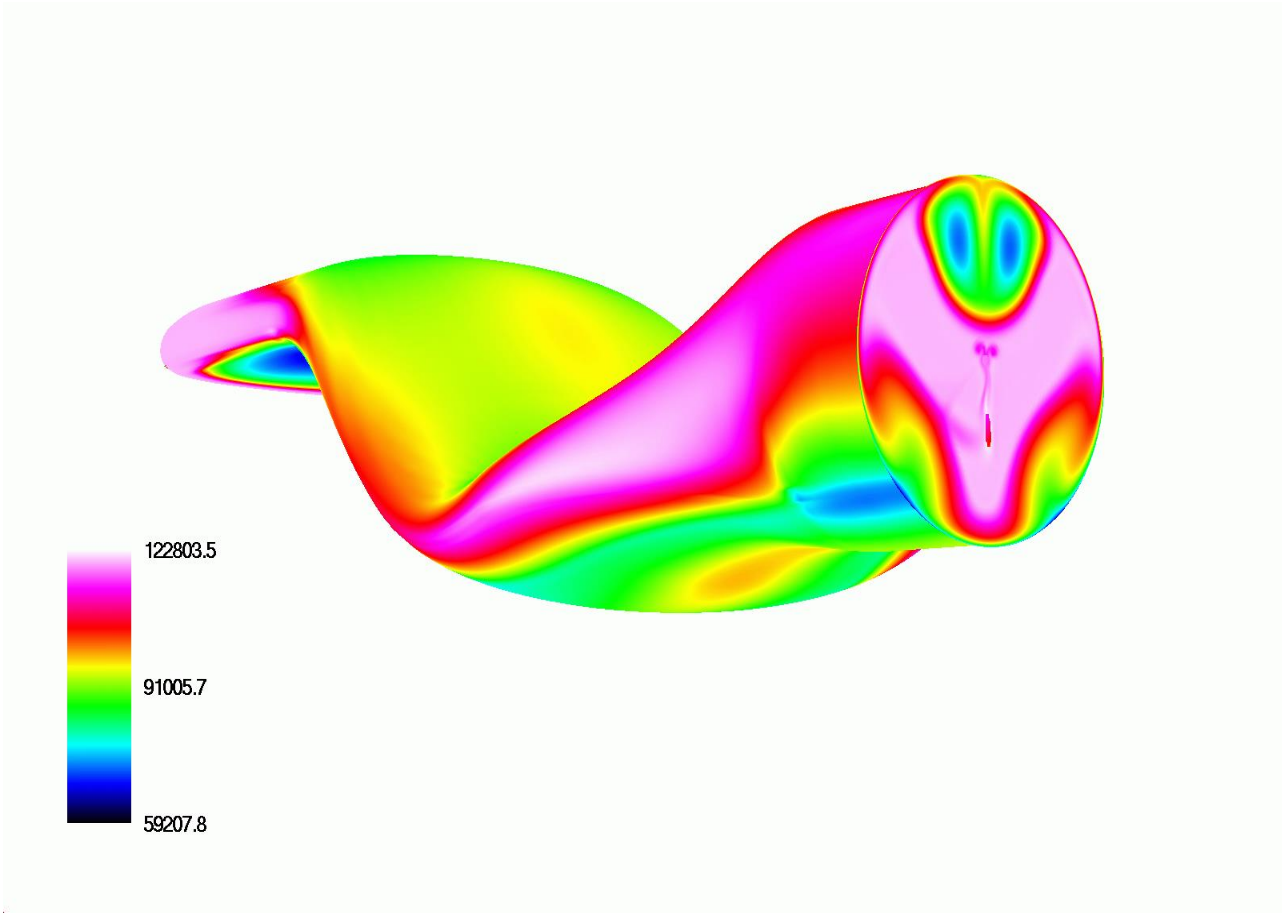
Comparison of Total pressure rise characteristics



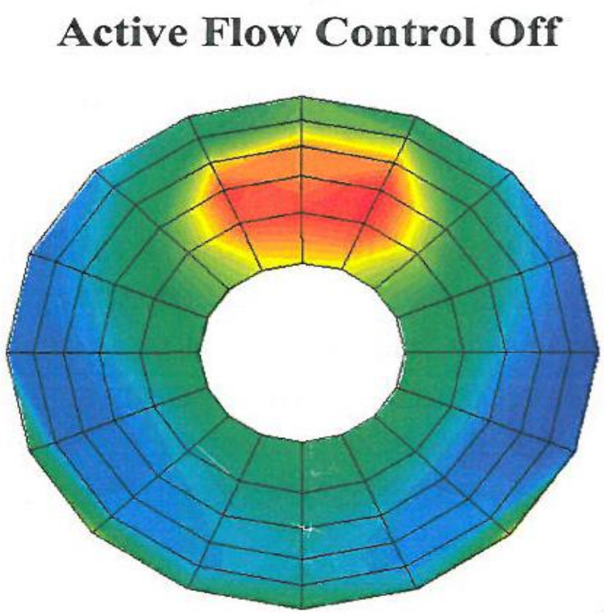
Measured Pt at AIP



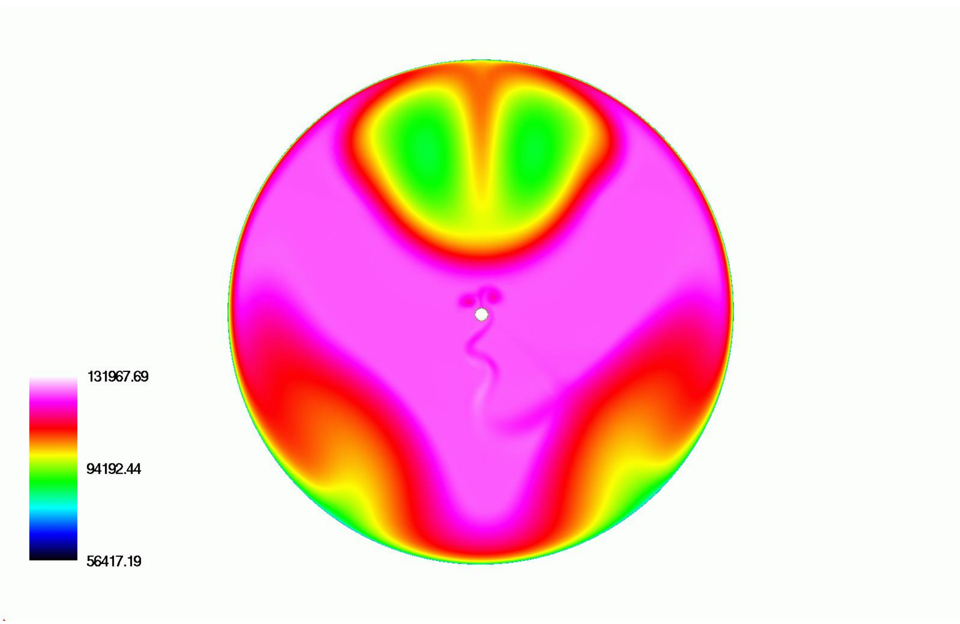
Total pressure near casing



Comparison of total pressure at AIP

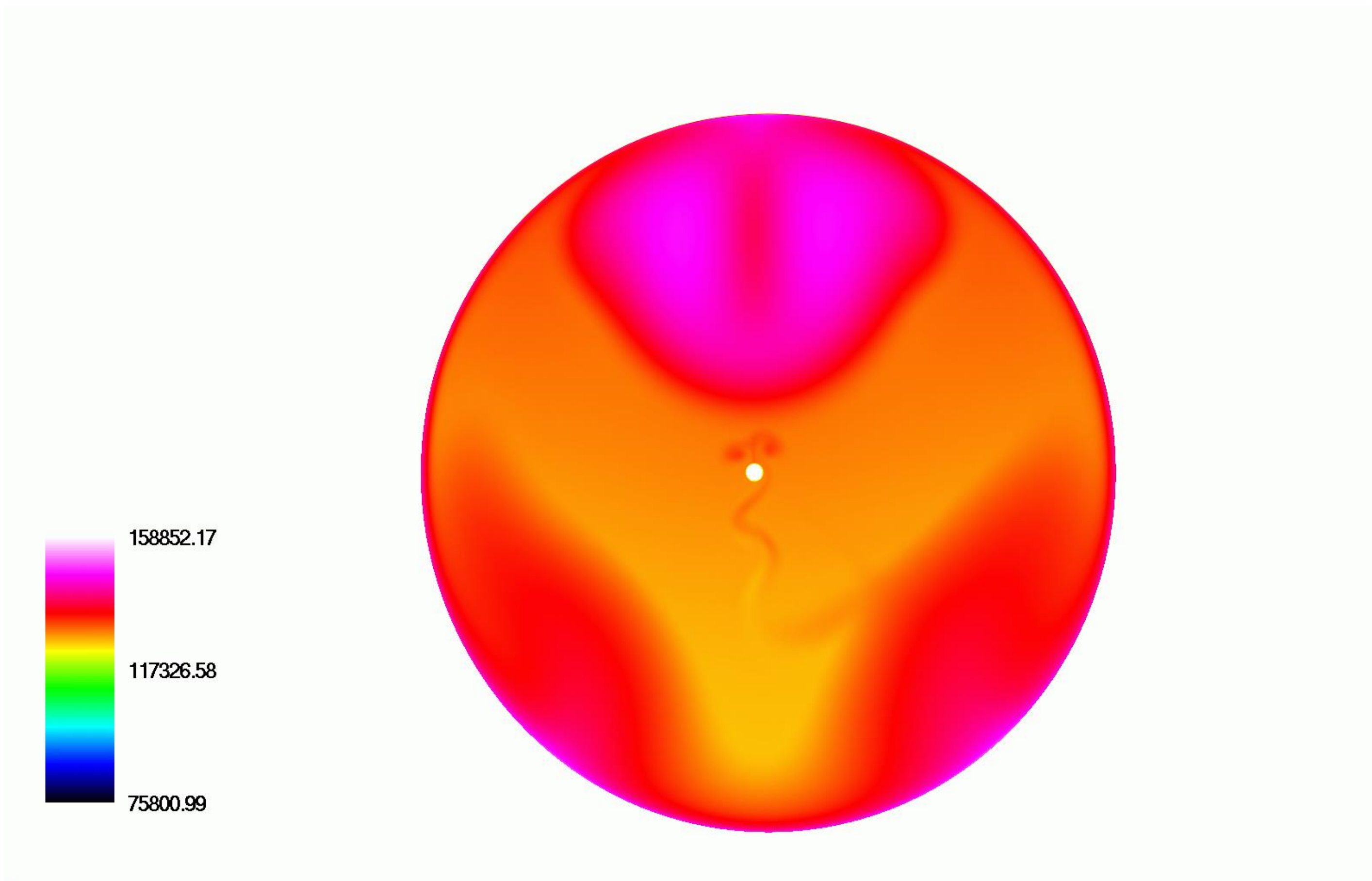


measurement

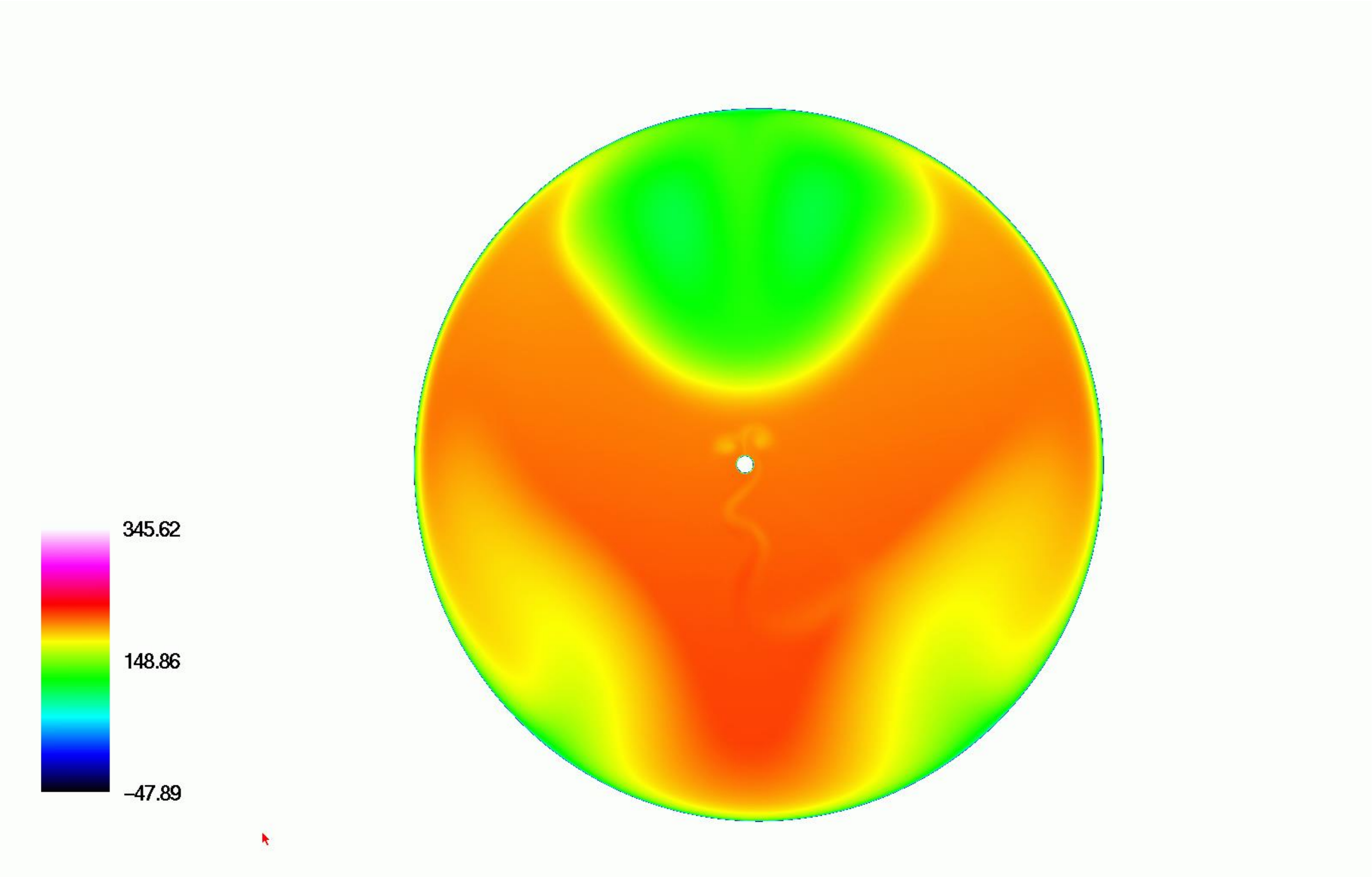


simulation

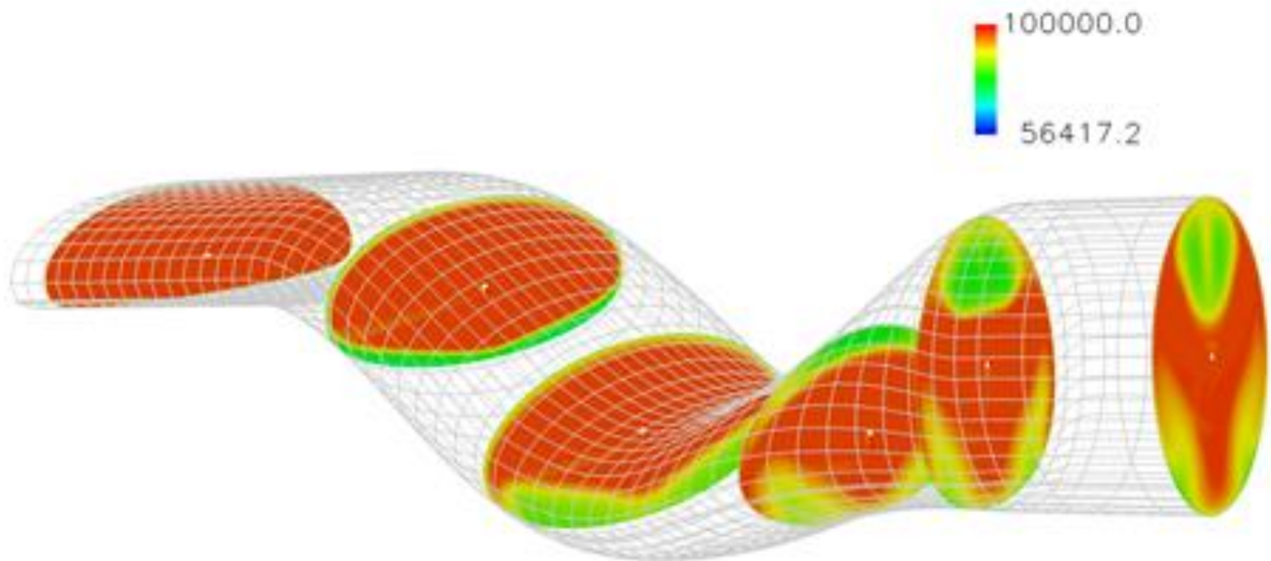
Total temperature at AIP



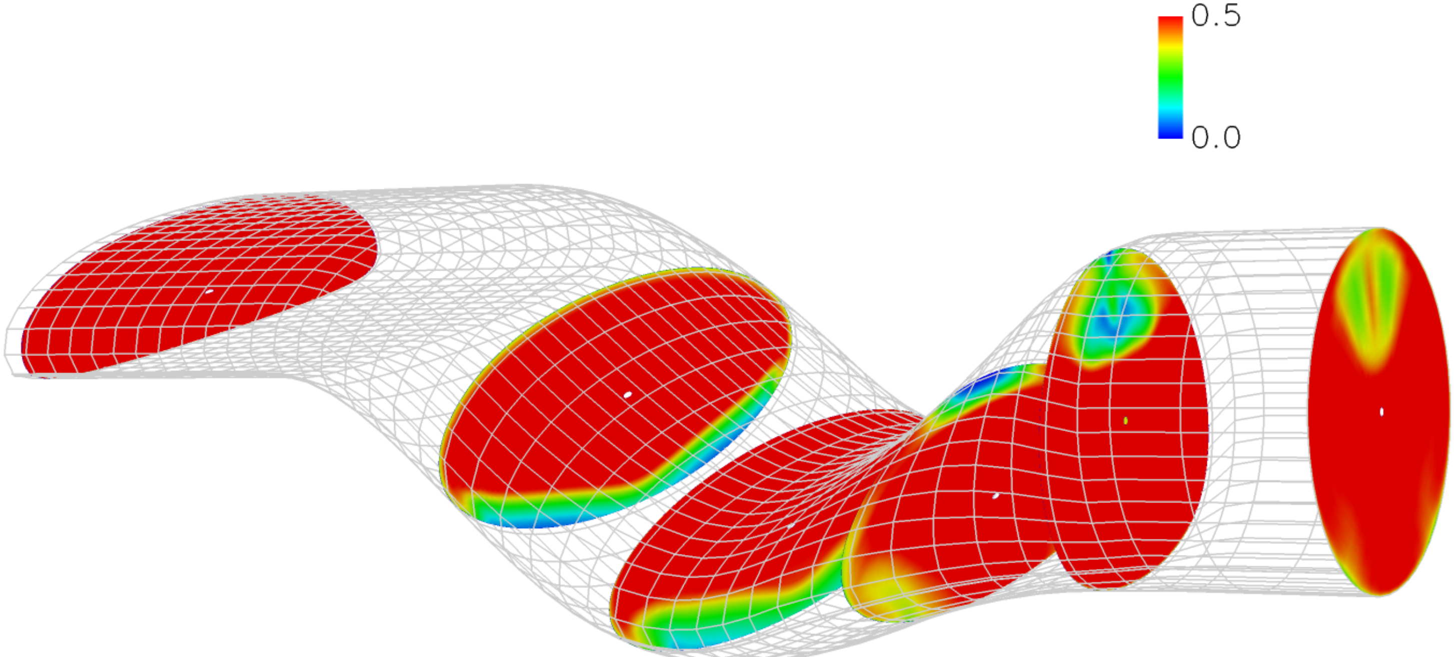
Axial velocity at AIP



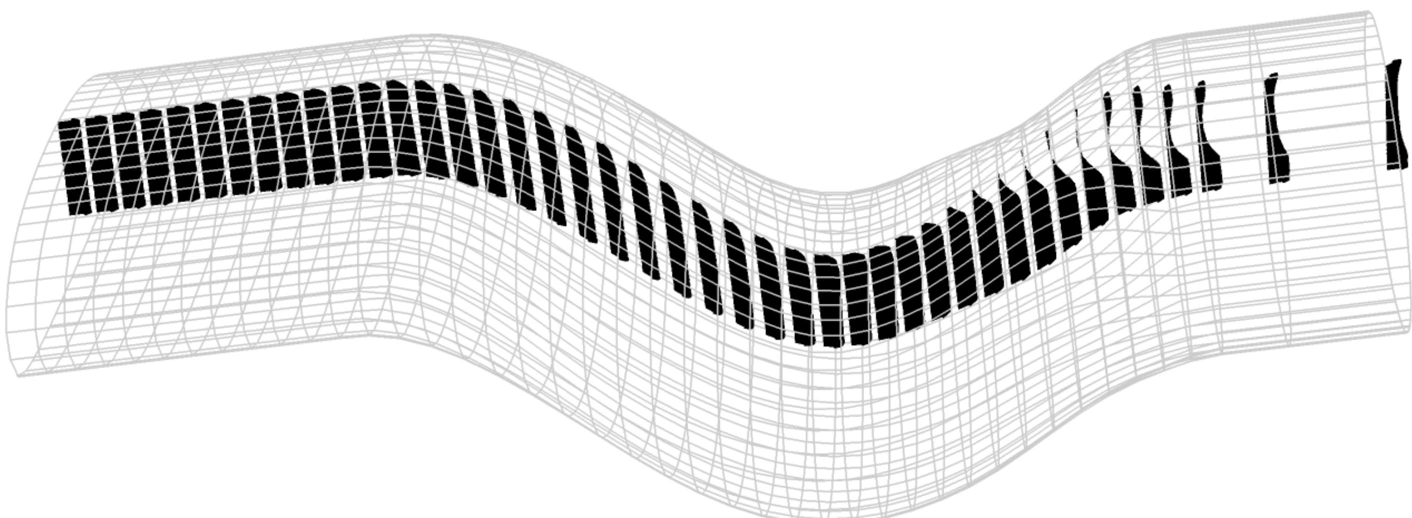
Development of static pressure through the inlet



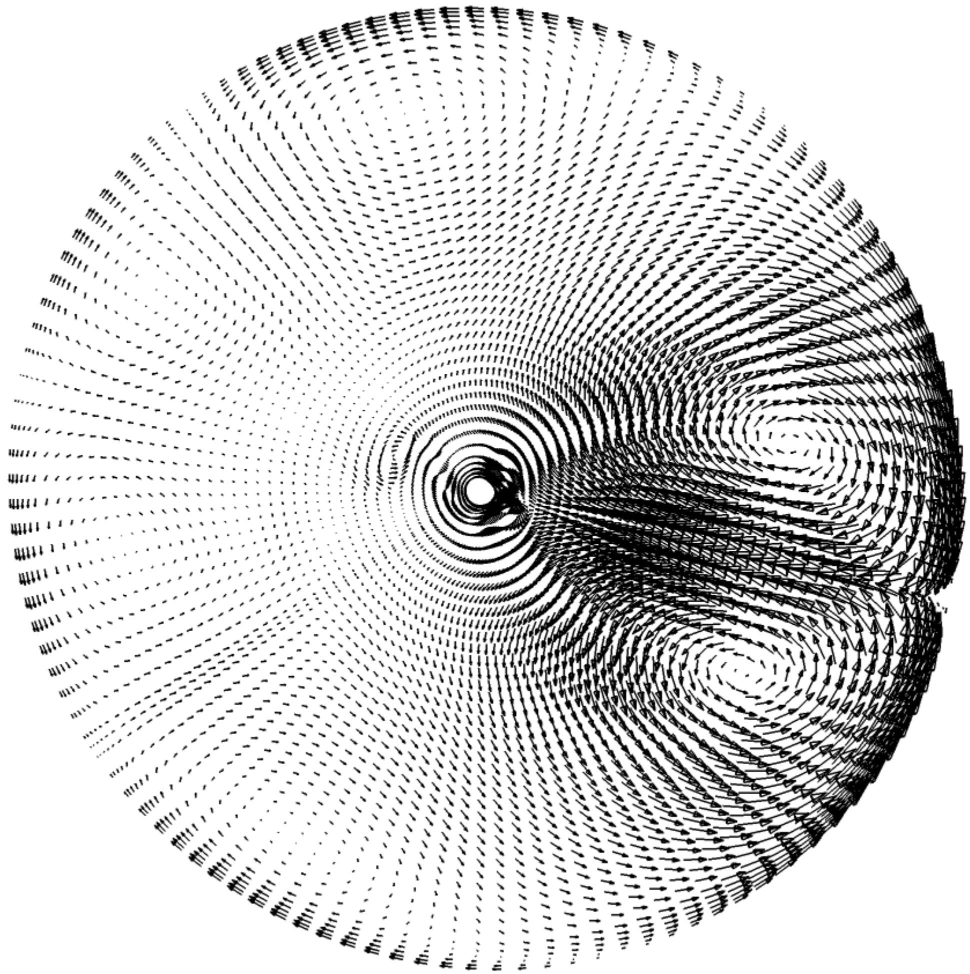
Development of Mach number



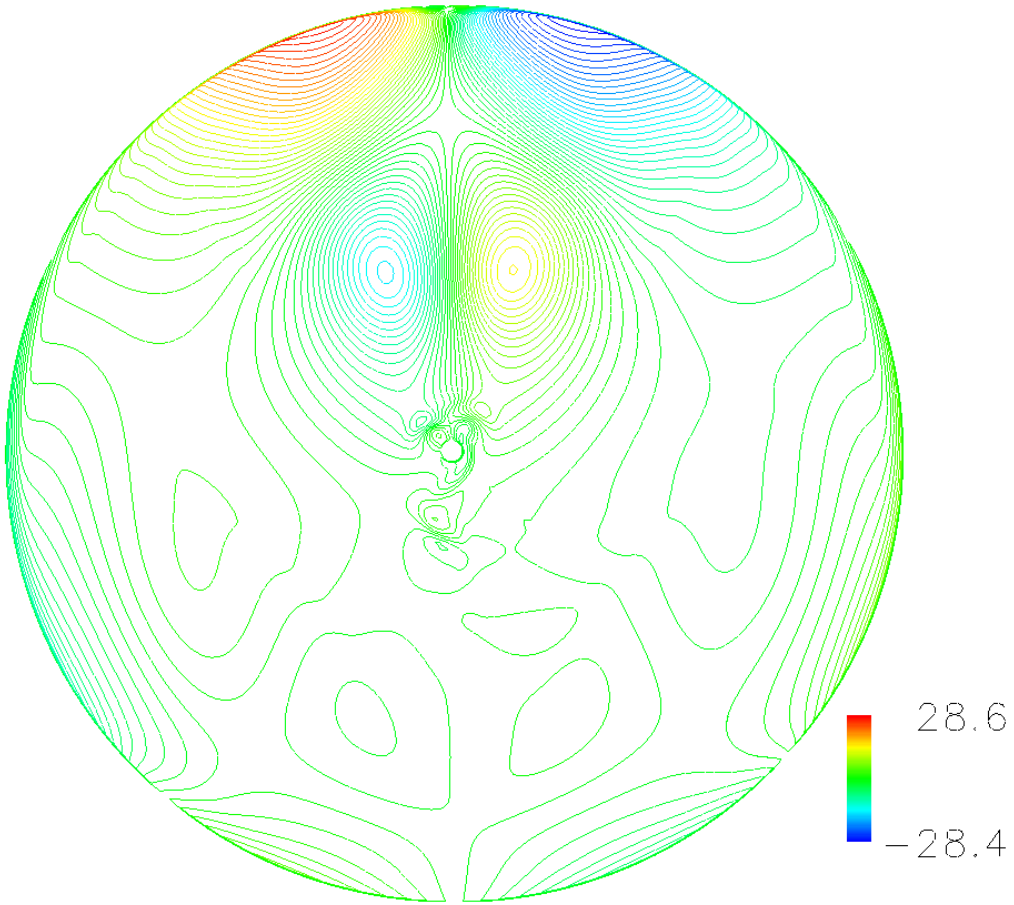
Instantaneous velocity vectors at the centerline



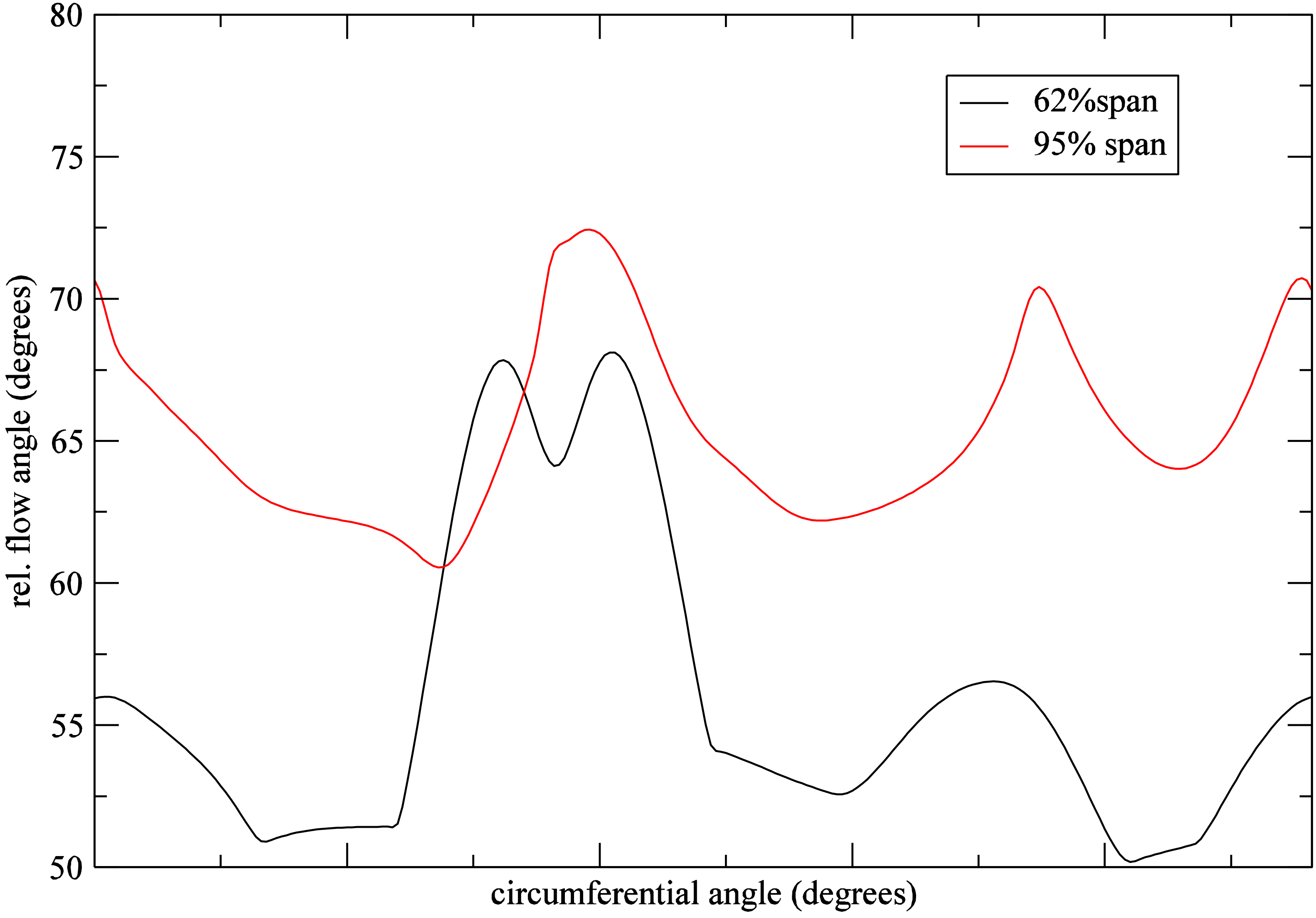
Instantaneous velocity vectors at AIP



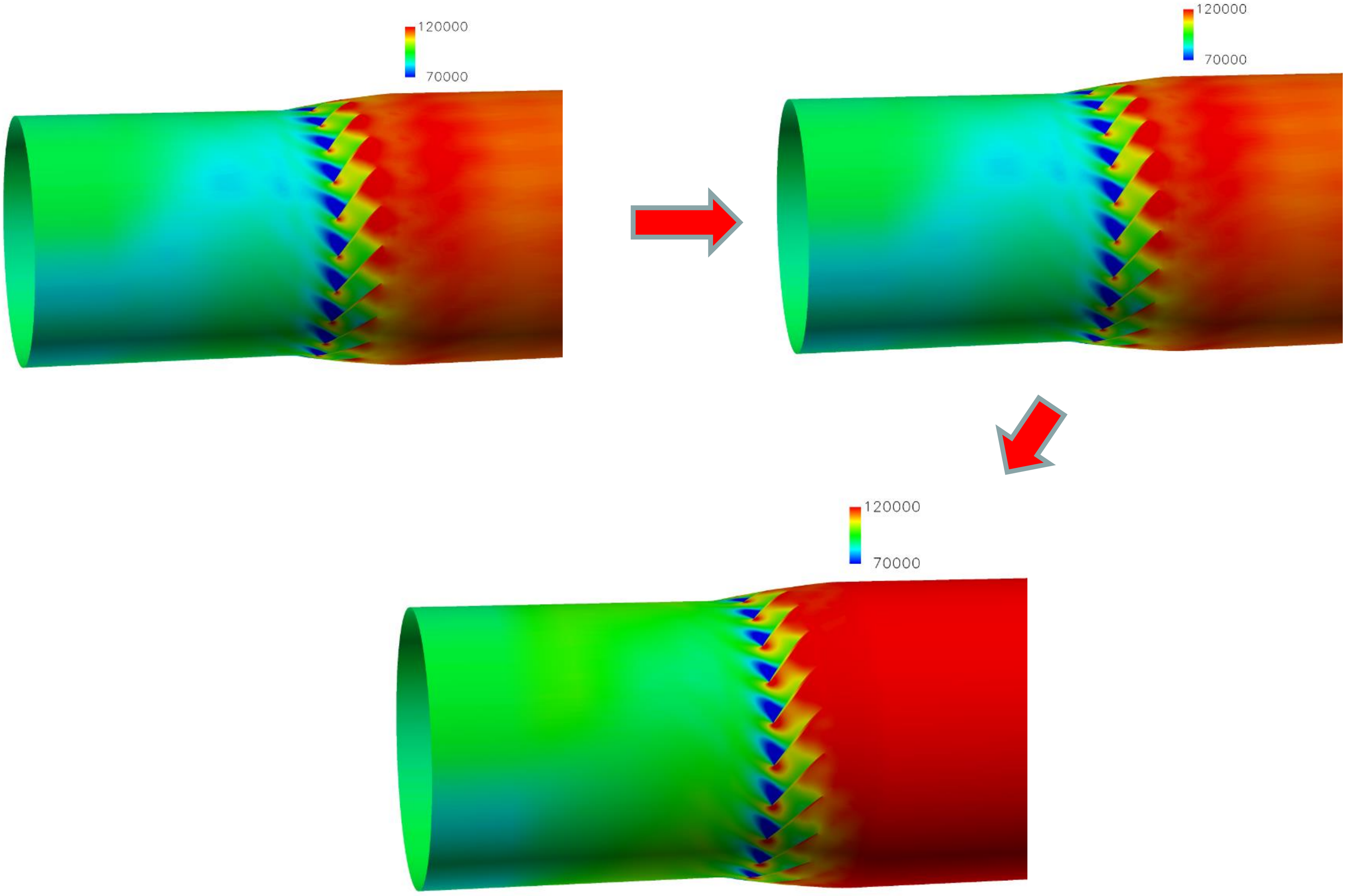
Instantaneous flow angle at AIP



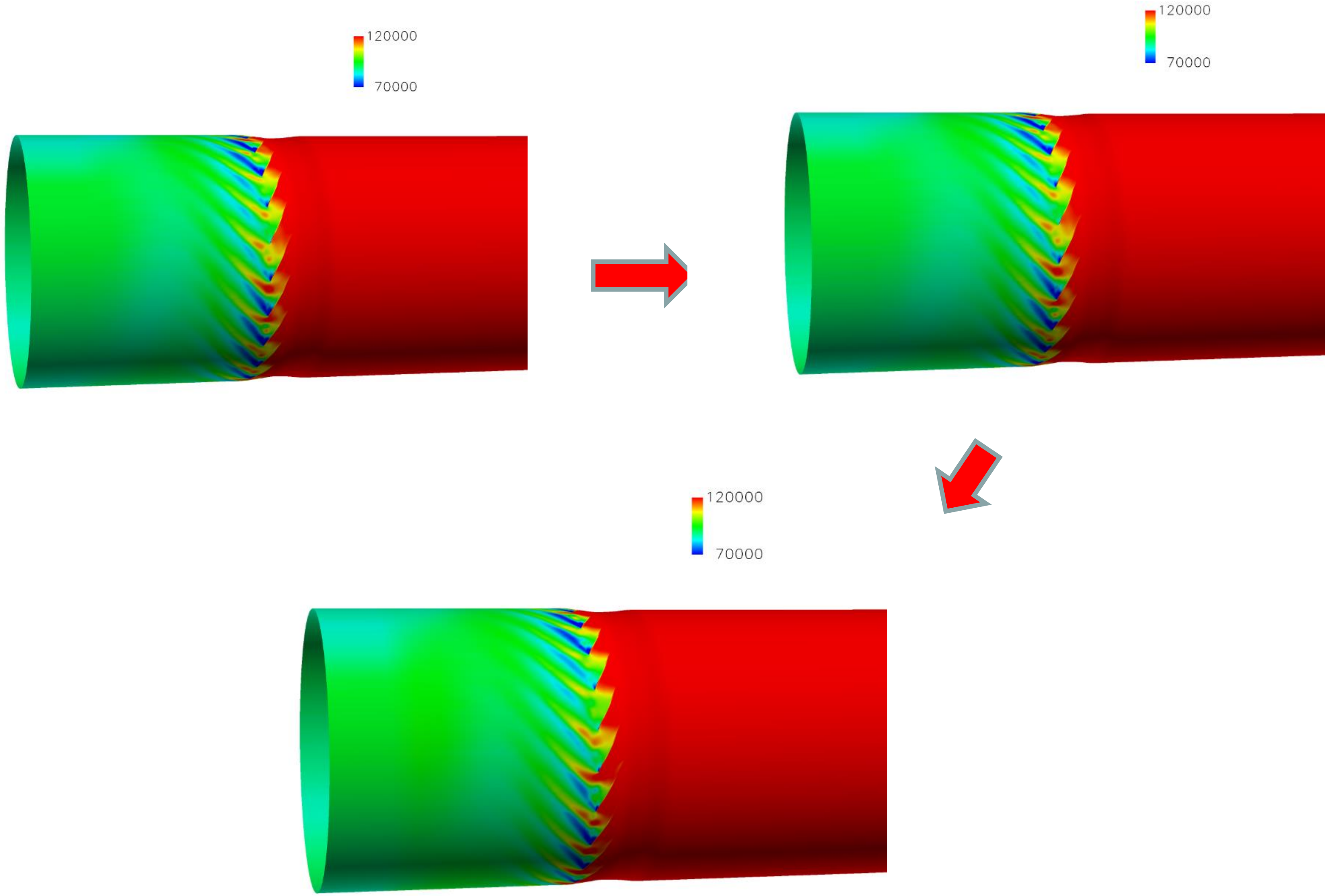
Relative flow angle at AIP



Instantaneous pressure contours at 65 % span



Instantaneous pressure contours at rotor tip



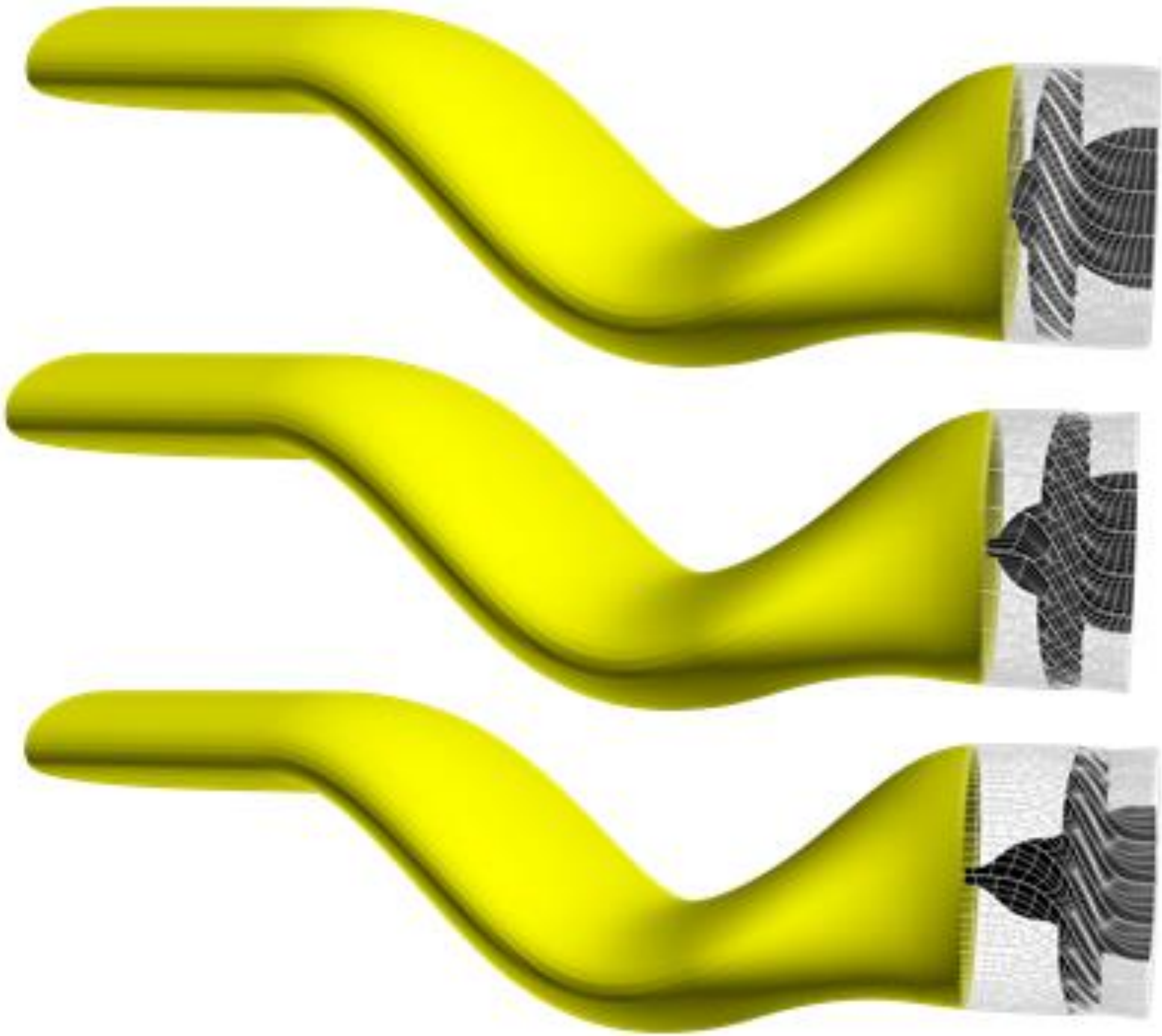
Observation from test and CFD simulation

- No decrease of stall margin with the inlet-generated distortion.
- Small change in compressor efficiency.

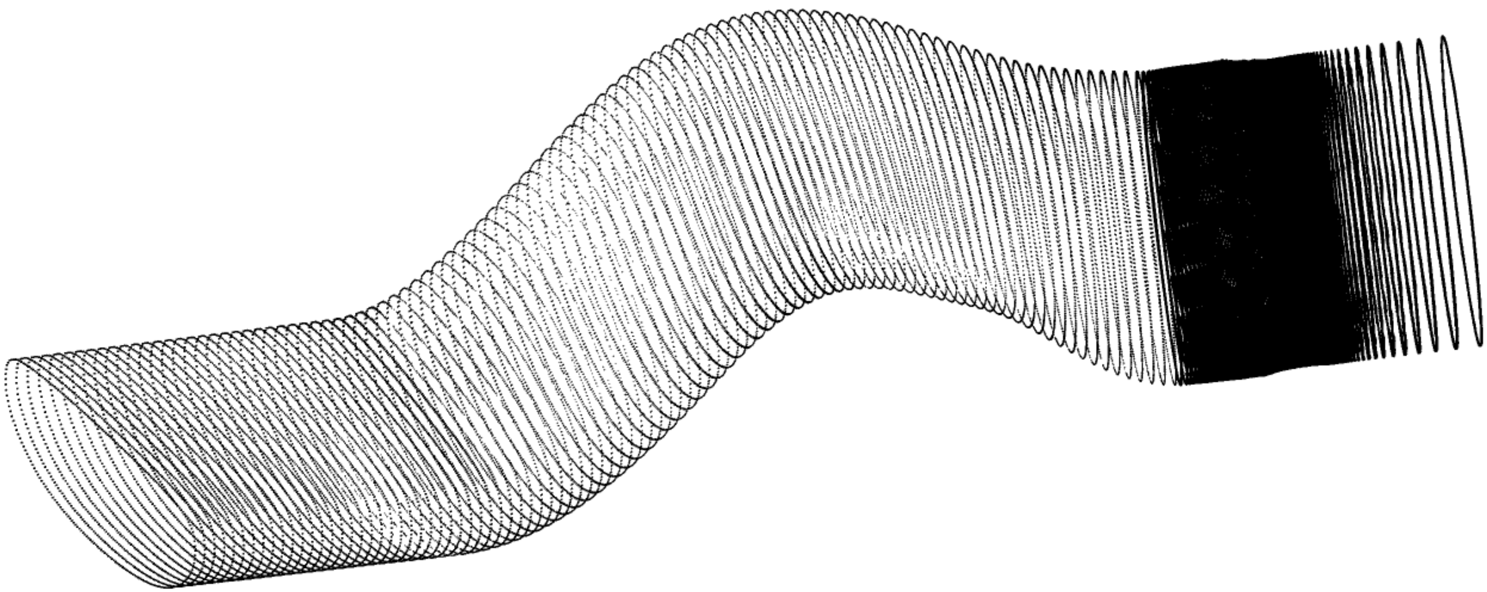
Current inlet/fan study

- Effects of distance between AIP and fan face.
- Effects of pattern and strength of inlet distortion.

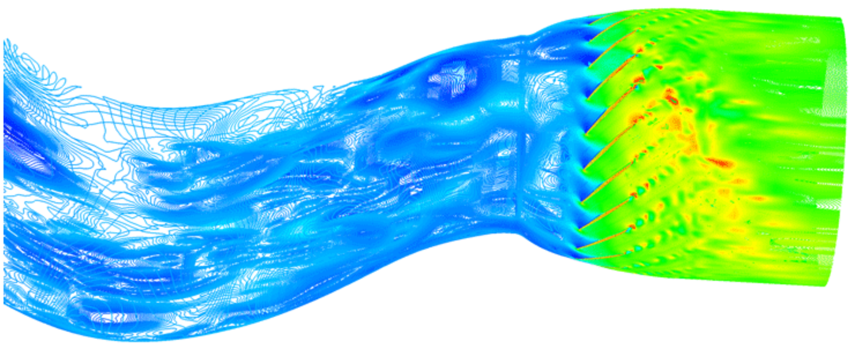
Effects of spacing between inlet and fan



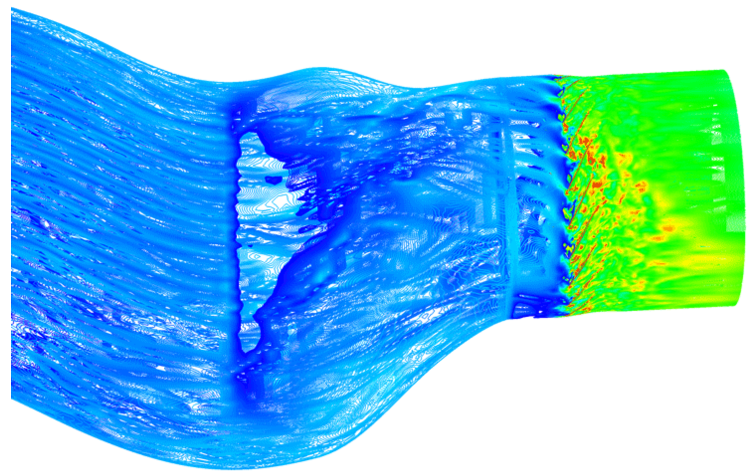
Velocity vectors at rotor tip, medium spacing



Absolute Pt with close spacing

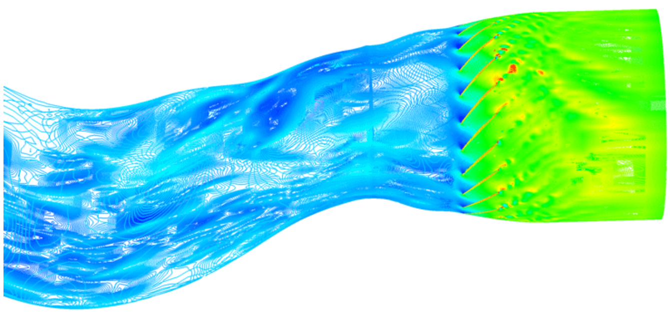


65% span

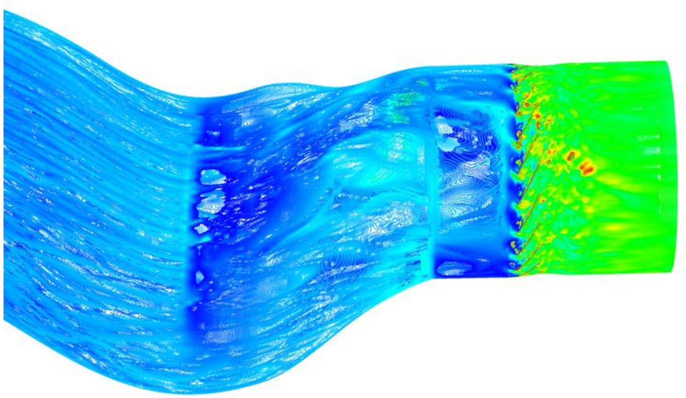


Rotor tip

Absolute Pt with more spacing

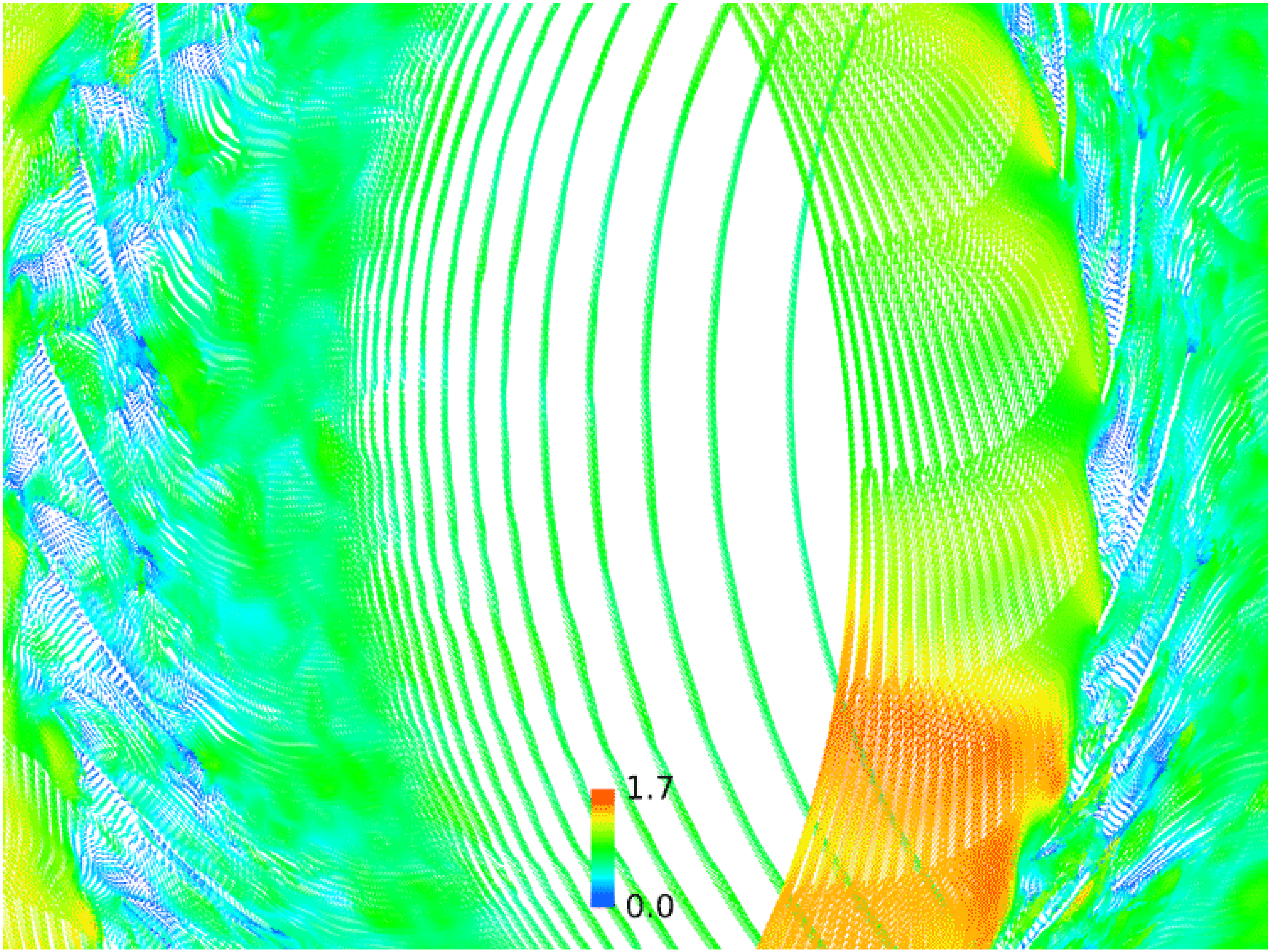


65% span



Rotor tip

Instantaneous velocity vectors at rotor tip



Instantaneous velocity vectors at 65% span